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QAM Signaling in Free Space Optical Communication Systems

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Abstract - Free Space Optical (FSO) communication systems are increasing their attraction from industries for an effective way for short distance communication wirelessly. FSO has high bandwidth, effective cost, requires no license and can be easily installed. The FSO system uses free space like air, vacuum etc. to transmit light over a distance. But the FSO solely depends on atmospheric conditions to transmit data. If the weather is not good then the possibility of having fading errors in the data received will become much more. The FSO communication system usually uses On-Off Keying (OOK) for transmission of data. It needs an adaptive threshold scheme for transmission in bad weather, but it's very complex to use adaptive threshold scheme with On-Off Keying (OOK). Hence, the use of modulation is required for carrying information in phase of RF carrier signal. Therefore use of Quadrature Amplitude Modulation (QAM) is done as it doesn't require adaptive threshold scheme.
Keywords-FSO, OOK, fiber, optical amplifier

1. Introduction

Free Space Optical (FSO) communication systems are increasing their attraction from Industries for an effective way for short distance communication wirelessly. FSO has high bandwidth, effective cost, requires no license and can be easily installed. The FSO system uses free space like air, vacuum etc. to transmit light over a distance. In earlier times Greeks used this technology for communication over a distance. But the FSO solely depends on atmospheric conditions to transmit data. If the weather is not good then the possibility of having fading errors in the data received will become much more. There can also be pointing errors in the signal. These errors are generally caused by misalignment of the transmitter and receiver, causing power loss and much more [1-4]. The FSO communication system usually uses On-Off Keying (OOK) for transmission of data. It needs an adaptive threshold scheme for transmission in bad weather, but it's very complex to use adaptive threshold scheme with On-Off Keying (OOK). Hence, the use of modulation is required for carrying information in phase of RF carrier signal. Therefore use of Quadrature Amplitude Modulation (QAM) is done as it doesn't require adaptive threshold scheme[5-6].

2. Free Space Optical Communication System

Free space optical (FSO) communication system is a way of transmitting data over short distances effectively and fast. It is done wirelessly. The Free Space refers to air, vacuum or anything from where light can travel without any distraction. The FSO communication is considered to be the next level of Optical communication. It consists of a transmitter at the sender's side and a receiver at the receiver's end. But the FSO communication totally depends upon the conditions of the atmosphere. Any hindrance in the atmosphere can cause major fading errors in the signal and at the same time can cause huge power losses. There's also occurrence of

pointing errors if the alignment of the transmitter and receiver is not proper. The FSO communication system usually uses On-Off Keying (OOK) for transmission of data. It needs an adaptive threshold scheme for transmission in bad weather, but it's very complex to use adaptive threshold scheme with On-Off Keying (OOK). The pointing errors can cause movement in the signal beam (Laser) [1].The FSO communication system uses Line Of Sight (LOS) transmission technique. Due to Line Of Sight connection pointing errors arise due to not proper alignment between transmitter and receiver. Fig (1) shows the block diagram of the FSO communication system. The new era requires the use of Free Space Optical (FSO) communication system because they are the need of future as they can be setup anywhere, doesn't require any license for the spectrum as the medium to transfer the information is basically free space (air, vacuum, anything from where light can travel without any distraction in its path. These Free Space Optical (FSO) communication systems are setup on places where the traditional optical communication system cannot be setup. The errors in the Free Space Optical (FSO) communication system can be very severe for the information signal as it can totally destroy the message in them.There are several other errors that can also occur in Free Space Optical (FSO) communication system due to not proper alignment of the transmitter and the receiver which are known as pointing errors. These errors can cause huge power loss in the system as to overcome these errors the beam width should be increased and that can be achieved by increasing the transmitting power. The normal modulation techniques like commonly used by Free Space Optical (FSO) communication system the On-Off Keying (OOK) cannot be used for the modulation here as they require adaptive threshold scheme for modulating to overcome atmospheric noises but it is very complex for this modulation technique. Therefore it requires the need to find some other modulation technique which can work more efficiently than the previous one.

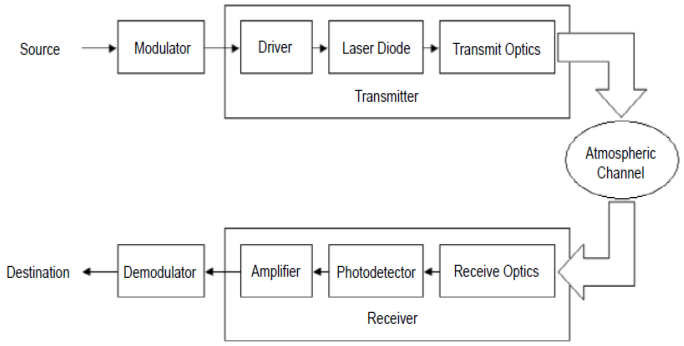

Fig.1: Block Diagram Free Space Optical Communication System

2.1 Pointing Errors

Pointing errors can occur due to not properly alignment of transmitter or receiver. They can cause huge power losses and noise in the signal. There are two main components of pointing errors:

1. Bore sight
2. Jitter
3. **Bore sight:** It is the displacement between center of receiver plane and beam path center. It's a fixed error.
4. **Jitter:** It is the random offset of beam center at detector plane. It's a random error.

3. Quadrature Amplitude Modulation (QAM)

Quadrature Amplitude Modulation (QAM) comes under the heading of Hierarchical Modulation which can modulate multiple data stream into a single stream [3]. Quadrature Amplitude Modulation (QAM) has higher spectral efficiency making it the most favored choice for digital transmission wirelessly. The QAM transmits two analog signals or two digital bit streams and changes the amplitude of two carries waves with the help of Amplitude Shift Keying (ASK). The two carrier wanes having same frequency are out of phase at 90°. This is known as quadrature. Though the frequency is equal they can add up but can also be separated coherently due to their orthogonal nature. Quadrature Amplitude Modulation (QAM)

is a composite modulation can transmit n bits by m symbols, hence, more bits can be transmitted at a given time [2].

4. Quadrature Amplitude Modulation (QAM) in FSO Communication System

Since Free Space Optical (FSO) Communication System is solely dependable on the condition of the atmosphere for transmission of data it most often uses On-Off Keying (OOK) for data transmission which requires an adaptive threshold scheme to work in bad atmospheric conditions like fog, mist etc., this adaptive threshold scheme is very complex to use by the On-Off Keying (OOK). Therefore, the use of this is not practical. And due to bad atmospheric conditions the use of modulation is required to carry information in a phase of RF carrier signal [4]. The Quadrature Amplitude Modulation (QAM) has increased its attraction for Subcarrier Intensity Modulation (SIM) in Free Space Optical Communication. QAM has higher spectral efficiency making it the most favored choice in transmission wirelessly. Quadrature Amplitude Modulation (QAM) based Subcarrier Intensity Modulation (SIM) requires no Adaptive Threshold Scheme providing better performance than On-Off Keying (OOK) in bad atmospheric conditions [4].Quadrature Amplitude Modulation (QAM) requires quite low bandwidth and accordingly the spectral efficiency is way more than other modulation techniques [4].

5. Working Model

The block diagram for the Free Space Optical (FSO) communication system with Quadrature Amplitude Modulation (QAM) based Subcarrier Intensity Modulation (SIM) is shown Fig 2. This system transmits a radio frequency signal which carries the information and two parallel waves of same frequency. The radio frequency signal modulates the optical signal. The Quadrature Amplitude Modulation (QAM) is taken here for modulating the optical signal and the radio frequency signal.

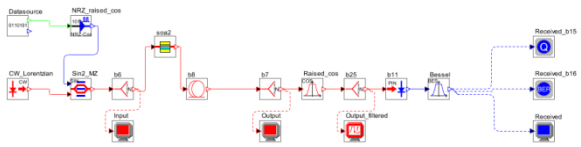

Fig2.Free Space Optical (FSO) communication system with Quadrature Amplitude Modulation (QAM) based Subcarrier Intensity Modulation (SIM)

This system can be used when noise from the surroundings is the major error in the signal as in the case of Free Space Optical (FSO) communication system where the atmospheric conditions play a major role in data transmission.

6. Simulation of the above system

The above system was simulated using Matlab and the outputs were shown in Fig 3 and Fig 4.The simulation was done on two atmospheric conditions:1. When the noise was low i.e. when the atmospheric conditions were not very poor. When the noise was at medium i.e. when the atmospheric conditions were at moderate levels. In both the conditions pointing errors were taken into account.

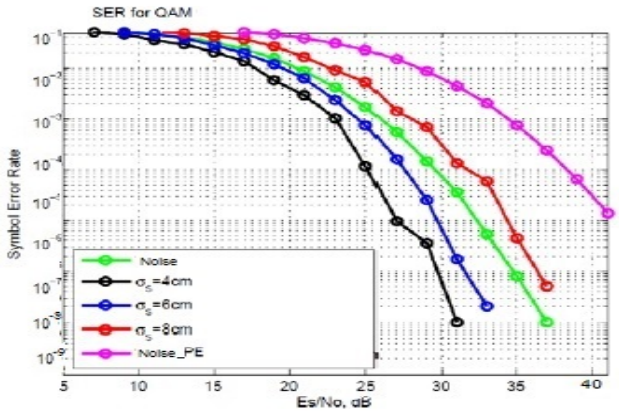

Fig3. Simulation of QAM-SIM in low atmospheric noise with presence pointing errors (PE)

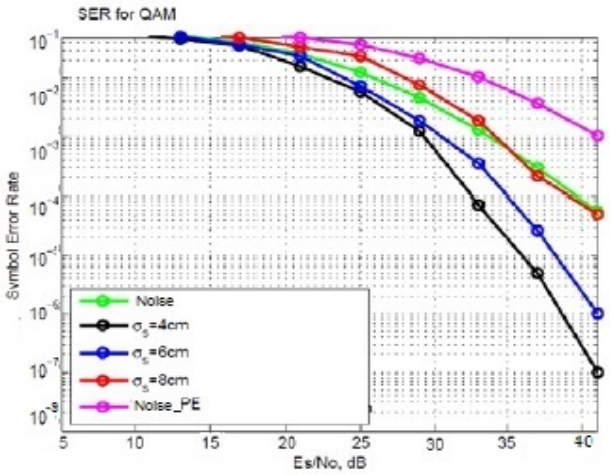

Fig4. Simulation of QAM-SIM in medium atmospheric noise with presence pointing errors (PE)

6. Conclusion

The simulations showed that the noise with presence of pointing errors could be reduced. The pointing errors can be overcome by increasing the width of the beam but it requires high transmission power. Since, the use of normal modulation technique used by Free Space Optical (FSO) communication system i.e. the use of On-Off Keying (OOK) is not efficient and at the same time complex while using in bad atmospheric conditions as it required an additional Adaptive Threshold Scheme to give better performance, we can use Quadrature Amplitude Modulation (QAM) technique as it doesn't require additional Adaptive Threshold Scheme and can perform even better than conventional On-Off Keying (OOK). Quadrature Amplitude Modulation (QAM) is the future in transmission of data wirelessly and at the same time the need of Free Space Optical (FSO) Communication System is equally important for communication where conventional communication setup cannot be built.

6. References

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